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**A STUDY OF THE COMBUSTION OF ORGANIC MATERIALS  
IN CLAY**

By

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**THESIS**

FOR THE

**DEGREE OF BACHELOR OF SCIENCE**

IN

**CERAMIC ENGINEERING**

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**COLLEGE OF ENGINEERING**

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THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

ALBRA HENRY WESSLER

ENTITLED.....A STUDY OF THE COMBUSTION OF ORGANIC MATERIALS.....

IN CLAYS

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF.....BACHELOR OF SCIENCE.....

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## I INTRODUCTION

The presence of organic materials in clays and their importance in the burning behavior of clays has long been a known fact. It was noticed that burning clays with high carbon content presented a very different problem from burning clays with low or medium percentages of carbon. In some cases where the carbon was very high the kiln would "burn itself" after a dull red heat was obtained. If the burning was not under absolute control at that point the kiln would over-burn causing a total loss of the contents.

Another peculiar circumstance in burning clay which is attributed to the presence of carbon, is the presence of a black core in the interior of the finished product. These cores may be due to carbon or to ferrous iron, or both. They may thus be developed in clays with no carbon but with a high iron content.<sup>1</sup> The burning of such clays presents a very interesting problem and one that must be worked out for each clay.

(a) Carbon in clay.— Carbon in clays occurs in a form closely allied to bituminous coal or as partially decayed vegetable tissue, such as roots and leaves. This starts to burn as the kiln attains a dull red heat. The vegetable matter burns readily and with no danger to the ware. All of our burning troubles are caused by the bituminous form of carbon. This form of carbon gives off a combustible gas which will burn on the surface of the brick if enough is present. This causes a rise in temperature which is not desired at this point. Experiments show that brick with 5% sawdust show no core at the end of 45 hours burning but with coal, the core



is still present at the end of this time.<sup>2</sup>

(b) Iron in clay.- Iron occurs in two forms in clay, depending on burning conditions. Ferrous iron forms in the presence of carbon with no excess air, while ferric iron results from excess air.<sup>1</sup>

(c) Critical period in burning.- Up to 110° "water of plasticity" is driven off. The water left in the clay coming from the dryer is usually called "hygroscopic water". From 110° to 500 or 600° the clay substance breaks up and the "chemical water" is driven off. The clay is now at a dull red heat and if air is circulating the carbon starts to burn. The rate of burning increases with increase in temperature. The carbon near the surface burns first, leaving a dark core in the center. As the air attacks the carbon in the interior of the brick, the passages between the grains of clay become choked with  $\text{CO}_2$  or  $\text{CO}_2$  and CO which must diffuse outward before fresh air can enter and burn the carbon. This process requires time, since the diffusion of gases through small capillaries is a slow process. Between 900 and 1000° the pores start to close up, so the passage of air is restricted. It is absolutely necessary to have complete oxidation before this contraction has progressed to any great extent. At 1000° the ferrous iron fuses in contact with the clay, and so if oxidation is not complete and the ferrous iron is not oxidized to ferric iron at this point, we have formed a slag which slows up oxidation due to the increasing difficulty of air entering into the interior. In bad cases the bubbles entangled with the fusing slag cause the brick to swell and bloat.<sup>3</sup>



(d) Steam.- The state of the atmosphere circulating around the brick during oxidation determines the rate at which fresh air penetrates the interior of the ware. The more air the better, as brick in badly ventilated parts of the kiln are more apt to have cores. The effect of steam in the kiln is to act as a screen preventing the entrance of air, so it is necessary to remove all steam as quickly as possible.

## II EXPERIMENTAL

### (a) Determination of the carbon content of the clay.-

The clay used in this work was obtained from the Coates' Manufacturing Company, Fort Dodge, Iowa, and was a black shale used in the making of brick and tile. The carbon content was determined by the "Scott Wet Process"<sup>4</sup>, using the apparatus shown in Fig.No.1.

One gram of the clay was mixed with 10 grams  $K_2Cr_2O_7$  as an oxidizer in flask A. 50 cc. of  $H_2SO_4$  was admitted through B and then boiled for five minutes. Before adding the  $H_2SO_4$ , the system was cleaned out by drawing air through the train for five minutes, and then weighing U tubes C and D. After oxidation was complete the two U tubes were weighed again. The increase in weight showed the amount of  $CO_2$  absorbed by the Na Ca. This amount multiplied by .2727 gave the amount of carbon, which divided by the amount of clay used and multiplied by 100 gave the percentage. Three preliminary tests were run and then three complete tests, giving 8.93, 8.3 and 9% of carbon.





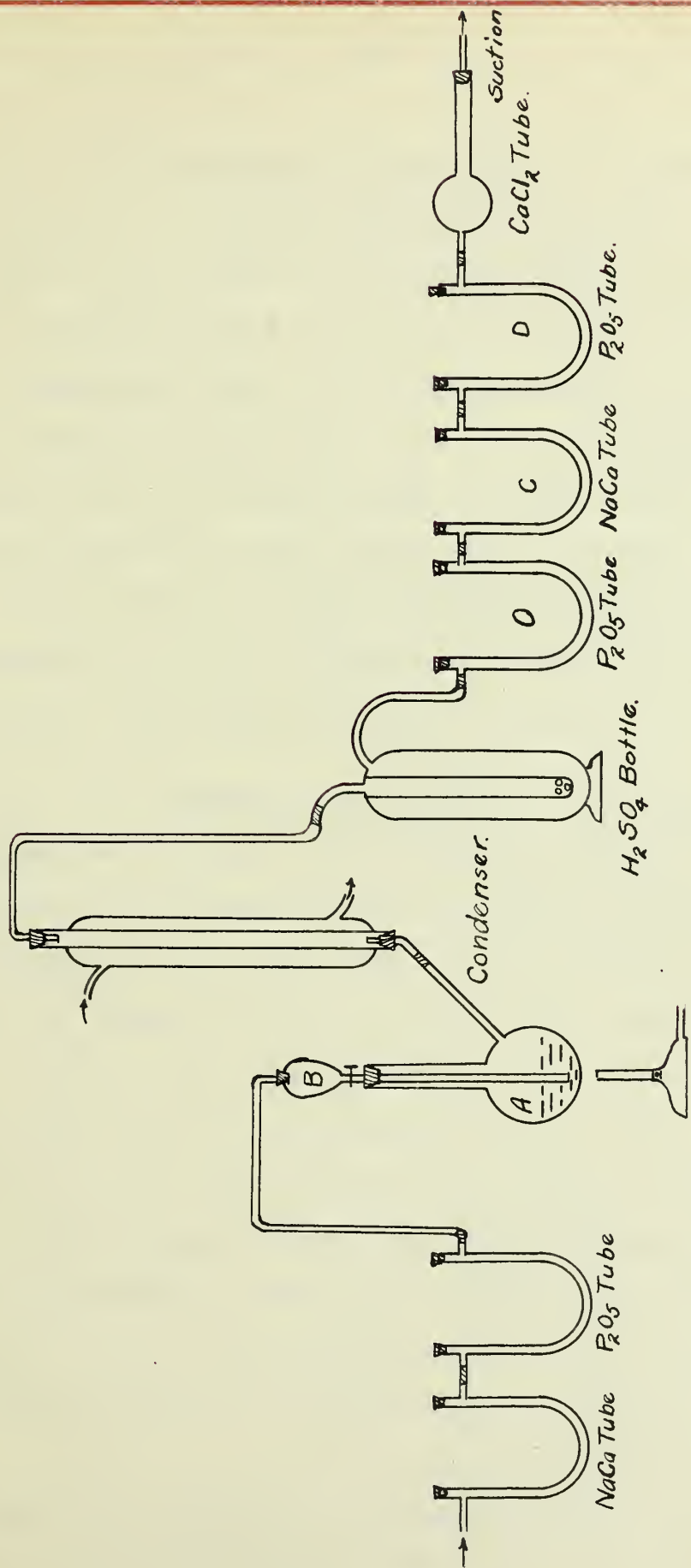


Fig #1





(b) Principle of the method.- To carry on the study of the combustion of organic materials in clay, it was desired to find the amount of  $\text{CO}_2$  given off during oxidation. To accomplish this it was necessary to find some way of measuring this gas. Our first attempt was with the use of gas meters. The volume of gas and air was measured by one meter, the gas then passing through a  $\text{CO}_2$  absorption train and then through a second meter. The difference in the two meter readings would give us the  $\text{CO}_2$  content of the gas. This process was not successful due to the fact that the hydrocarbons in the gas tended to interfere with the accuracy of the meters. The apparatus finally adopted is shown in Fig.No.2.

(c) Apparatus and method.- The furnace used was made of a 4" porcelain tube and covered with an asbestos covering. It was wound with No. 20 chromel wire, connected in series with an ammeter and a rheostat used to vary the current. The outer end of the furnace was closed with a perforated disk, after the sample was in place. At the other end a porcelain tube connected with a condenser and drip bottle to collect the moisture from the gases. The drying of the gases were completed by passing through a  $\text{H}_2\text{SO}_4$  wash bottle. The  $\text{CO}_2$  was absorbed by passing through a solution of KOH made by dissolving 300 grams of KOH in 300 grams of water. The gases and air then passed through another drying tube containing  $\text{H}_2\text{SO}_4$  which collected all water given up by the KOH solution.

. This absorption train was placed on a balance pan so the amount of  $\text{CO}_2$  absorbed could be weighed. The draft through the furnace was obtained by means of



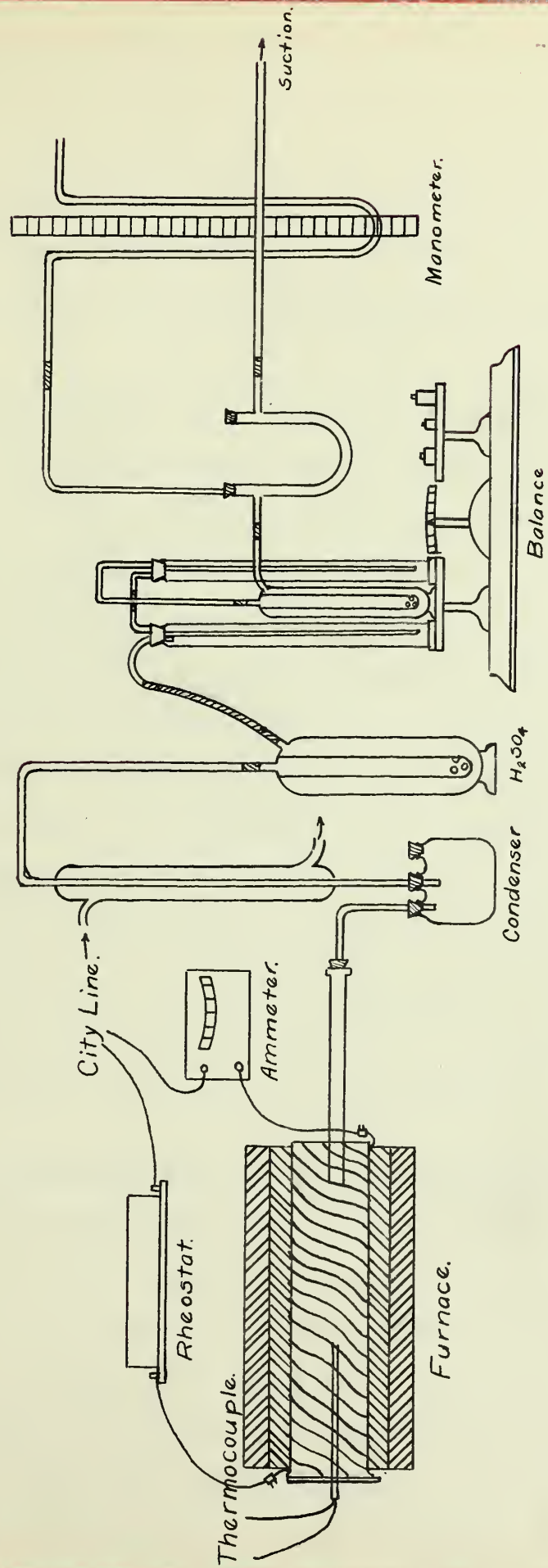


Fig # 2



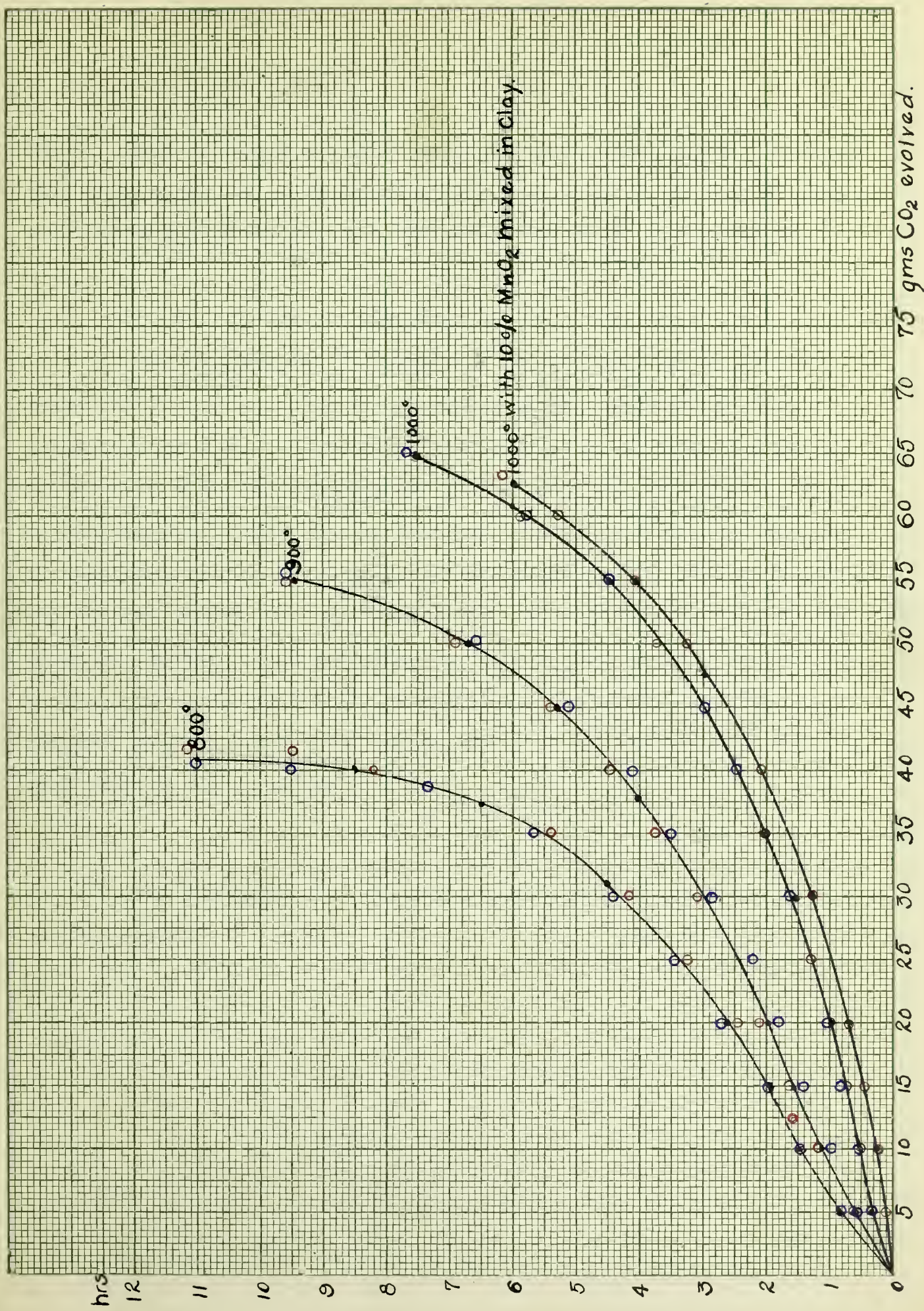
a vacuum pump run by a small motor. A manometer which had been calibrated by means of a gas meter was attached to the train. By reading the manometer, the volume of air passing through the furnace was known.

(d) Procedure.- The cube of clay was placed in the center of the furnace with a thermocouple beside it. Pieces of brick were placed in front of the cube so as to divert the incoming air to all parts of the brick. The suction pump was started so as to produce a draft of 2 cubic feet of air per minute through the furnace. This draft was kept constant through all the experiments. The air would burn the carbon to  $\text{CO}_2$  and pass through the  $\text{H}_2\text{SO}_4$  bottle into the KOH solution where the  $\text{CO}_2$  was absorbed. These bottles were placed on a balance so the amount of  $\text{CO}_2$  absorbed in the KOH solution could be weighed at a given time. The temperature was kept constant for each run. Several tests were made at each temperature and the results checked. The results obtained are shown graphically in Fig. No. 3. The points for a given run are indicated by the use of the same color.

(e) The use of  $\text{MnO}_2$  as an oxidizing agent.- It was desired to know what effect  $\text{MnO}_2$  would exert upon the oxidation of the clay. With this idea in view some of the clay was ground to pass through a 20 mesh screen and cubes of clay were made mixing 1, 3, 5, 8 and 10% of  $\text{MnO}_2$  with the clay. The clay was pressed in a 2" x 2" x 2" mould and burned in a muffle kiln. Draw trials were drawn at 500, 600, 700, 800 and 900 degrees. No decrease in the size of the cores could be seen, except in the ones containing 10%











MnO<sub>2</sub>. This decrease could be seen for each trial drawn, showing that MnO<sub>2</sub> acted as an oxidizer at all temperatures at which trials were drawn and with the same effect at all these temperatures.

### III RESULTS

(a) Discussion of results.- The results obtained are rather what one would expect from preceding knowledge of the oxidation process. The slight difference in the data for different runs at the same temperature is due to the difference in texture of the samples. The curves show the marked increase in the rate of oxidation for each increase in the temperature. It is interesting to note the slight increase in the rate of oxidation with the addition of MnO<sub>2</sub>. It would be interesting to find the increase in the rate of oxidation at a constant temperature, with varying volumes of air. The time available was not sufficient to take up this side of the problem.

(b) Summary.- The results of the investigation are shown on Fig. No. 3.

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